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A DIGITAL COMPUTER PROGRAM FOR DETER-  
MINING THE PULSE TO PULSE RADAR  
CROSS SECTION ON A DYNAMIC TARGET

Frederick Elwood Meyett



# United States Naval Postgraduate School



## THEESIS

A Digital Computer Program  
For Determining the Pulse to Pulse  
Radar Cross Section on a Dynamic Target

by

Frederick Elwood Meyett, Jr.  
Lieutenant, United States Navy  
B. S., United States Naval Academy, 1963

Thesis Advisor:

Robert L. Miller

June 1971

Approved for public release; distribution unlimited.



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Submitted in partial fulfillment of the  
requirements for the degree of

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M 573  
C.I.

## ABSTRACT

This paper describes the design and use of SIGMA, a computer program for the calculation of radar cross section of a dynamic target on a pulse to pulse basis, using the MK 25 Fire Control Radar. The program is written specifically for use on the Scientific Data Systems 9300 computer in FORTRAN IV, but is readily adapted to other data processing systems. The input data base is composed of magnetic tape recordings of instrumented radar range and signal strength. Outputs include target cross section and range, and mean cross section and range in printed tabular listing, in graphical form, and on digital magnetic tape.



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## I. INTRODUCTION

Radar cross sections for various simple geometric objects have been calculated and experimentally verified. Cross sections for more complex targets such as fixed and rotary wing aircraft have been measured. This is usually done by constructing a scale model of the target. The model is then placed in an anechoic chamber and illuminated with appropriate RF energy at a frequency scaled to the model. The aspect of the model with respect to the sensor is then varied and the backscattered energy is recorded. From this data cross section as a function of aspect and frequency is obtained.

The examination of cross sections of geometric objects is useful in an academic approach to diffraction phenomenon, but bears little significance to the engineering of a radar system. Measurement of cross sections of models is at best, a first-order approximation to the determination of back-scatter cross section. The model is static and rests in a controlled environment. A dynamic target does not show a smooth, modelled shape. Further, backscatter is modified by turbine engine modulation and changes in diffraction of the wave fronts due to airfoil control surfaces and fuselage vibration. Since target size has a pronounced effect on the determination of radar system performance, it is then necessary that cross section be measured on dynamic targets.

One method for dynamic measurement of cross section uses a ground-based fire control radar. Prior to tracking the target to be measured, the radar system is calibrated by tracking a 6-inch metal sphere lofted by a helium-filled balloon. Automatic Gain Control (AGC) voltage and



range are recorded. This calibration permits many of the parameters in the radar range equation to be considered as a single term. Immediately following the calibration, the target is tracked and AGC voltage and range are recorded. Comparing ranges to target and sphere for equal AGC voltages, cross section for the target can be calculated. While this method is a definite improvement over static measurement, disadvantages still exist. The AGC circuit serves to integrate the target data such that only mean cross sections can be calculated. Instantaneous data is lost.

By recording the pulse to pulse variation in signal strength and computing a cross section for each pulse, much statistical data can be gained. For example, a spectral analysis of cross section variation could be performed. With a radar properly instrumented for recording azimuth and elevation data, correlation of the spectral lines with pattern recognition could produce target signatures. The computer program SIGMA described by this paper performs the first of these operations. The received signal is converted to radar cross section on a pulse to pulse basis. The output data is then placed in a form conducive for statistical analysis by digital techniques. Although the program was written specifically for use on the Scientific Data Systems 9300 computer, it is readily adapted to other user oriented systems.



## II. THEORY

The concepts for measurement of radar cross section on a pulse to pulse basis are similar to those outlined by Cunningham [Reference 1]. The fire control radar that is used in the measurement is first calibrated by tracking a target of known radar cross section, in this case a metallic sphere. Since the sphere presents a constant aspect and its cross section may be calculated, a functional relationship between radar range and signal strength can be found. Armed with this relationship and known constant sphere cross section, the unknown target is tracked, and signal strength and range are recorded. Radar cross section for the target is ultimately found by forming a ratio of radar range equations. Each range equation may be reduced to a relatively simple form if measurement of the target immediately follows calibration, and atmospheric effects are neglected. By proceeding in this manner, system parameters such as transmitted power, noise figure, integration improvement factor, system losses and antenna gain, may be assumed to remain constant. Let this then be the case as described and further, let  $\alpha$  represent those terms which remain constant between calibration and measurement. Then the simplified form of the radar range equation is written as:

$$R^4 = \frac{\alpha\sigma}{S} \quad (1)$$

where:  $R$  = radar range, meters

$S$  = detected signal, watts

$\sigma$  = radar cross section, meter<sup>2</sup>

$\alpha$  = constant, meter<sup>2</sup>-watts



In the MK 25 Fire Control Radar System, the voltage output from the boxcar circuit is readily accessible and more conveniently measured than actual signal power at the receiver input. The functional relationship between this voltage and signal power is not linear because of the circuitry involved, but may be generally written:

$$S = f(V)V \quad (2)$$

where  $V$  = boxcar circuit output voltage.

Equation (1) may be rewritten:

$$R^4 = \frac{\alpha\sigma}{f(V)V} \quad (3)$$

and further, let:

$$\beta(V) = \frac{\alpha}{f(V)} \quad (4)$$

then Equation (1) becomes:

$$R^4 = \frac{\beta(V)\sigma}{V} \quad (5)$$

or:

$$\beta(V) = \frac{VR^4}{\sigma} \quad (6)$$

and:

$$\beta(V_s) = \frac{V_s R_s^4}{\sigma_s} \quad (7)$$

where Equation (7) has been subscripted for the calibration data on the sphere. Since  $R_s$  and  $V_s$  are measured and  $\sigma_s$  is calculated, there exists a value of the function which describes all system parameters. If  $R_s$  and  $V_s$  are continuously recorded, then the lumped parameter function  $\beta(V)$  becomes continuous. For the calibration track, the sphere radar



cross section is calculated:

$$\sigma_s = \pi r^2 \quad (8)$$

where  $r$  = radius of sphere, meters.

It should be noted that equation (8) applies only if the circumference of the sphere lies in the Optical region. The Optical region is defined as that region of size where the ratio of circumference to wavelength is equal to or greater than 10.<sup>1</sup>

An identical form of equation (7) is written for the target to be measured:

$$\beta(v_t) = \frac{v_t r_t^4}{\sigma_t} \quad (9)$$

Since the same radar system tracks both sphere and target,  $\beta(v_s) = \beta(v_t)$ , provided  $v_s = v_t$ . Substituting  $\beta(v_s)$  for  $\beta(v_t)$  in equation (9):

$$\frac{r_s^4 v_s}{\sigma_s} = \frac{r_t^4 v_t}{\sigma_t} \quad (10)$$

or:

$$\sigma_t = \frac{r_t^4}{r_s^4} \cdot \sigma_s \quad (11)$$

To solve for  $\sigma_t$  it is necessary to tabulate  $v_s$  and  $r_s$  on the calibration track. In a similar manner  $v_t$  versus  $r_t$  are recorded. Since  $\beta(v_s)$  must equal  $\beta(v_t)$  for  $v_t = v_s$ , then there exists a value of  $r_s$

---

<sup>1</sup> See Skolnik [Ref.2] for a discussion of radar diffraction in the Rayleigh, Resonance and Optical regions.



for each value of  $V_t$  and  $R_t$ . The value of radar cross section of the sphere is known. Thus, target cross section may be found directly for each value of  $V_t$ .



### III. INPUT DATA BASE

The input data base for both the calibration track and target track was provided to the computer by multi-channel wideband magnetic tape recording. Data extracted from the tape consisted of three signals: boxcar circuit output voltage, range marker ramp voltage, and a trigger pulse. Since this data must be converted to digital form, a brief, examination of the waveforms encountered is relevant.

Consider first the dc level of the boxcar output. Output voltage from the boxcar circuit had a wave shape for a single pulse similar to that shown in Figure (1). The ideal(flat) response was corrupted by the low pass characteristics of the tape recorder and its associated matching networks at input and output. It then became necessary to sample this signal at a zero-crossing, delayed in time to allow sufficient damping. The required delay was determined from the recorder step response and was provided to the computer operator along with other parameters necessary for the analog to digital conversion.

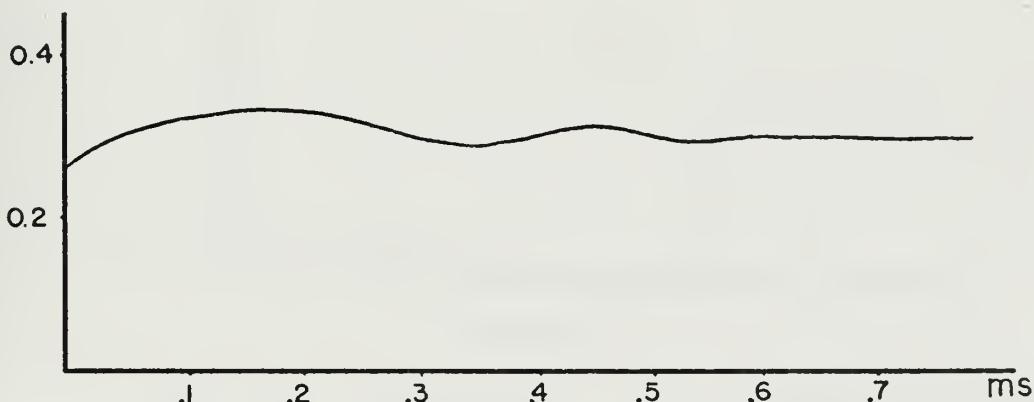


Figure (1)



The radar range marker was a ramp voltage generated by a servo driven potentiometer across a regulated dc power supply. The servo was geared to produce one complete revolution for each two thousand yards range. The servo rotated clockwise for increasing range and counter clockwise for decreasing range. The range ramp voltage was biased slightly negative so that the zero-crossing could be sensed in the computer program, and used to resolve ambiguities between increasing and decreasing ranges. The actual amount of bias is not important and will be discussed in more detail in Section IV. A typical wave form for increasing range is shown in Figure (2). Figure (3) illustrates a decreasing range. The slope of the ramp is proportional to target range rate.

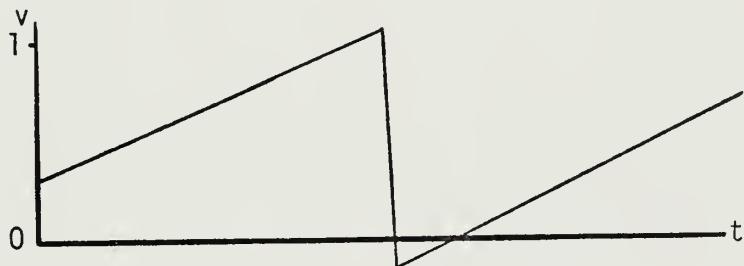


Figure (2)



Figure (3)

The trigger pulse was provided so that the required delay could be set for sampling the boxcar output. This pulse was generated within



the MK 25 Radar and was coincident with the Range Gate Enable signal. The time between pulses was the same as the pulse repetition period of the radar, namely 763 microseconds. A typical trigger pulse is shown in Figure (4).

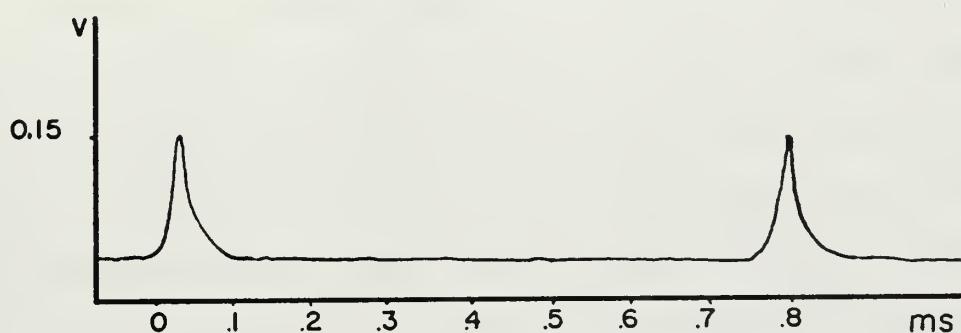


Figure (4)



#### IV. COMPUTER PROGRAM: SIGMA

##### A. GENERAL DEVELOPMENT

As described in previous sections, a sphere was tracked and the boxcar circuit output voltage, a function of signal strength, and the corresponding radar range were recorded for each pulse on magnetic tape. Similarly, a target of unknown radar cross section was tracked and the same measurements, boxcar output and range, were recorded. It then became a matter of reading a voltage on the target pulse, and since  $V_t$  must equal  $V_s$ , the corresponding range to the sphere could be found. Equation (11) was then solved for radar cross section. The most direct scheme to perform these operations with a digital computer would be to store in core memory discrete voltages and ranges for each pulse. In effect, a table would be constructed and a standard look-up routine could be used to extract the data. However, this procedure was neither practical nor economical because of the extreme size of the input data base. A typical calibration track, lasting fourteen minutes, resulted in over one million data points. Assuming that this amount of data could be stored, the time required by the look-up routine to extract one point would be prohibitive.

The need for such a cumbersome table was eliminated by finding the functional relationship between range and boxcar output voltage, described in Equation (3). This was done by calculating the mean signal voltage and mean range for every 1024 pulses, which resulted in a new data set of approximately one thousand points. The functional relationship was then found by constructing a curve from the data set



using a least-squared polynomial fit, with the optimum degree of fit determined by application of the F-Ratio test. The polynomial thus found, together with Equation (11) were entered into a single computational program to generate radar cross section on a pulse to pulse basis.

## B. COMPUTATIONAL SCHEME

SIGMA consists of four separate programs written in FORTRAN IV, each containing subprograms written in either FORTRAN IV or META-SYMBOL. Partitioning of the program in this manner facilitated development in that segments of the main program could be selected according to the amount of computer time available. Further, partitioning made possible more rapid isolation of programming errors and shorter turn around time. Extensive use was made of magnetic tape for input and output operations. The use of tape and partitioning was brought about partially by the limited core memory (32K) of the SDS 9300. While appearing to be an inconvenience, the use of tape allowed the results of all data conversions and intermediate calculations to be examined in detail. This was particularly useful in the analysis of noise spikes and their subsequent reduction. If desired, however, one can utilize the overlay structure of the computer and the four separate programs may be compacted into a single segmented routine with essentially one input tape and one output tape.

### 1. Calibration Data

Signals to be processed are provided to the computer on magnetic tape in analog form having the wave shapes shown in Section III. In order to reduce this data the signals are first converted to digital



form using the COMCOR Ci 5000 analog computer, and the Scientific Data System 9300 digital computer in hybrid configuration. The data is fed into the Ci 5000 from an Ampex Model SP-300 tape recorder, sampled at 1320 cps., digitized into binary words, and written on magnetic tape. This entire operation is performed by the program "A/D".

Voltages written on tape by "A/D" are in the form of 24 bit word integers, scaled by amplification during the sampling process on the Ci 5000. It is desirable to restore this data to its original form in floating point notation for ease of handling and output. Program "DATA SHAPER" performs this function. In addition to converting the voltages from an integer representation to a 48 bit real number, the program applies scaling to account for analog amplifier gain. Further, as the range voltages are converted, the 2000 yard discontinuity is sensed, and radar range is generated directly. These ranges and their corresponding boxcar voltages are then stored and averaged, one record at a time. (One record contains 1024 data pairs.) Both the average values and the pulse to pulse values can be listed by the line printer. Since the record averages are used to derive the functional relationship between  $R_s$  and  $V_s$ , these are written on magnetic tape.

The last phase of processing on the calibration data is to find the polynomial describing the relation of  $R_s$  to  $V_s$ . Program "FIT500" is used for this purpose. FIT500 reads in the record averages, selects up to 500 data pairs, and computes a least-squares fit to the degree specified by the namelist input. Since the boxcar output is a quadratic function of signal power, a second degree fit is used. The program also executes an F-Ratio test and calculates errors of the



coefficients generated. The program outputs the polynomial coefficients, the F-Ratio, a tabular listing of the input data with computed dependent variable and error.

This concludes the processing of data for the sphere track. The coefficients computed by FIT500 are used in the program "SIGMAGEN" to calculate radar cross section.

## 2. Target Data

Boxcar circuit output voltage and radar range for the target being measured is processed in much the same manner as the calibration data. The target signals are first processed by program "A/D" for an analog to digital conversion. This digital output then serves as an input to the program "DATA SHAPER", resulting in a magnetic tape on which is written boxcar circuit output voltage and radar range in yards for each pulse. This tape serves as the input data base for the program "SIGMAGEN", which computes the target radar cross section for each pulse. SIGMAGEN provides a variety of output options, including both magnetic tape and line printer. In addition to the pulse to pulse calculation, the program also averages each record (1024 pulses), and computes an overall mean cross section for selected range intervals. Further, the input tape need not be started at the load point, but may be advanced to any given range by the program. This permits small spans of range to be examined without the need to output an entire tracking run.



## C. IMPLEMENTATION

### 1. Program "A/D"

#### a. Analog Program

A/D was originally designed to perform an analog to digital conversion on any signal generated within the Ci 5000 with sampling rates up to 12,000 sps. For the conversion necessary in computing radar cross sections, the analog program shown in Figure (5) is used. Throughout this program and all others, boxcar output voltage is labeled S; radar range, R; and range gate trigger, SYNC. Both R and S channels from the tape recorder are fed to separate 50 gain amplifiers on the analog patch board. The gains are not critical but should be chosen so as to provide a working voltage level within the useful range of the Analog Digital Converter unit (ADC) in the SDS 9300. The limits of the ADC are  $\pm 99.99$  volts. The maximum tape recorder output voltage is approximately 1 volt RMS. S and R channel amplifier outputs are patched directly to trunks T500 and T501 respectively.

The SYNC channel output is patched through a 1.0 mfd. capacitor to a 100 gain amplifier. Amplifier output is patched to a comparator, the trigger level of which is controlled by a hand set potentiometer. This comparator outputs a logic signal to two delay flops. The first delay flop is used to set the 600 microsecond delay of the logic trigger pulse with respect to the SYNC pulse. The second delay flop is used to adjust the width of the logic trigger pulse. Output from the second delay flop is fed to trunk T211, an interrupt line to the digital computer. Both delay and width can be set by displaying the SYNC and logic trigger pulses on the CRO. If more



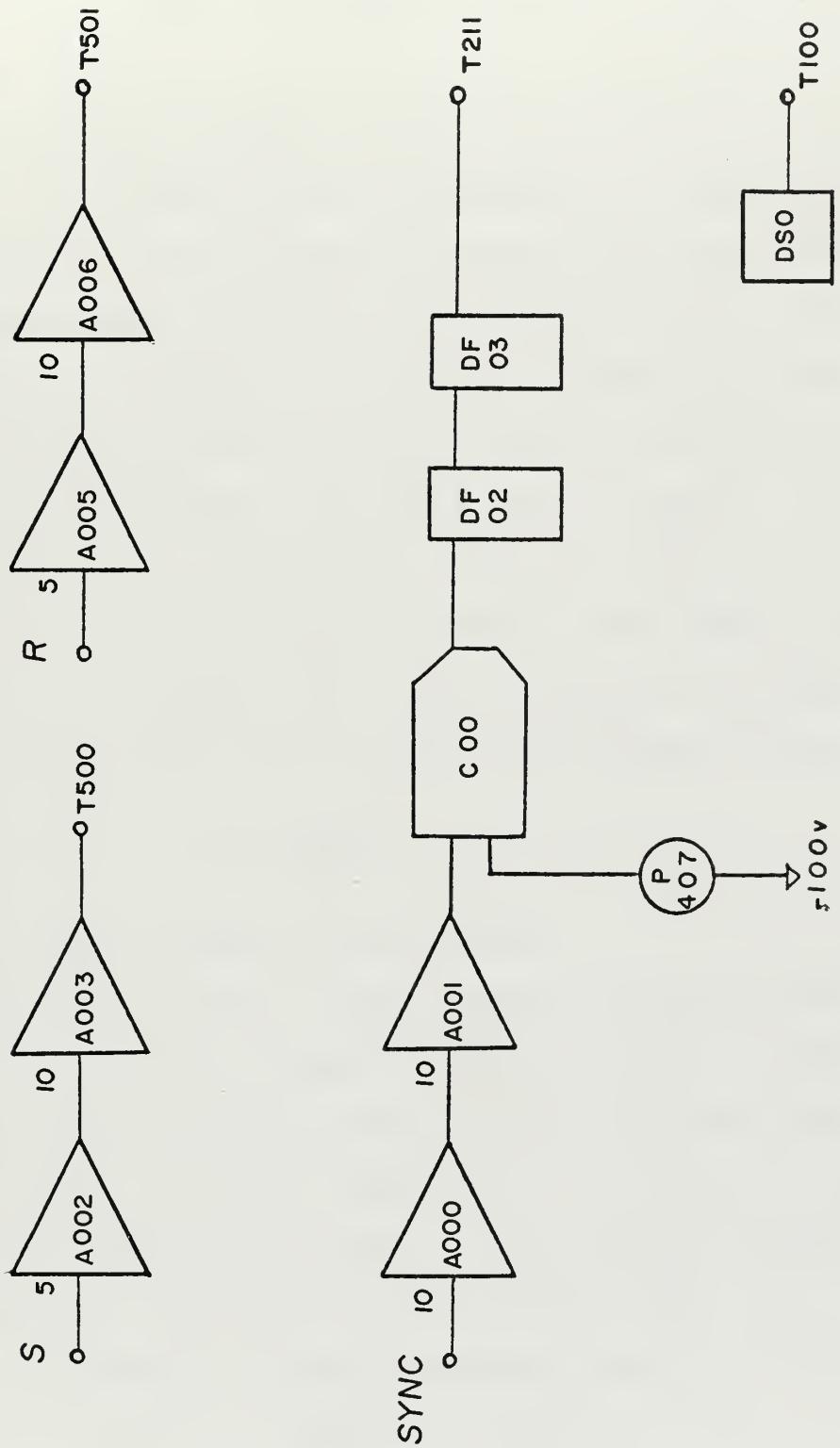


Figure (5)



precision is required, a period counter can be used. To complete the analog program, switch DS0 is wired to trunk T100, a test line to the SDS 9300.

b. Digital Program

The digital portion of A/D consists of a main program and one subroutine written in FORTRAN IV, and two subroutines written in META-SYMBOL. Signals to be converted are fed to the ADC on the trunks specified above. If DS0 is in the ON position then line T100 has a logic level present, the interrupts are enabled, and the sampling and conversion process begins. Values of R and S are stored in array IBUF, dimensioned (2048). When the array is full, the values are written on magnetic tape. This constitutes one record of 1024 values of R and S, written in 24 bit integer form. The actual value of the integer, N, is computed by the SDS 9300 according to the following relation:

$$N = \frac{E \cdot 2^{23}}{100.0} \quad (12)$$

Where E = value of sampled voltage from ADC.

The program will continue to sample, convert, and output to tape one record at a time until a stopping criteria is reached. To stop sampling, DS0 can be switched OFF, or a record limit can be set and entered as namelist input. A/D offers a number of control options. The computer will ask the operator for an option via the teletype. The option number is entered by the operator. The control options are:

Option (1) - enter new namelist data

Option (2) - perform A/D conversion

Option (3) - write "END OF FILE" on tape

Option (4) - rewind tape



Option (5) - skip files

Option (6) - read tape, output to line printer

Option (7) - read tape, output to strip chart recorder

The namelist inputs, entered on the teletype, are:

NREC = total number of records to be written on tape

NCHAN = number of signal channels

NSAMP = 2048/NCHAN

ITAPE = logical unit, magnetic tape drive (integer)

NDEL = number of milliseconds (times 11) delay between  
DAC outputs for Option (7).

## 2. Program "DATA SHAPER"

The output from program "A/D" is in the form of 24 bit integers.

The relation between the integer form and the actual value of the voltage sampled is given in Equation (12). The purpose of program "DATA SHAPER" is to convert these integer values to 48 bit real numbers by performing the inverse of the operations indicated in Equation (12), and applying a scale factor to account for gain. Additionally, the program computes the average values for each record. The input data base consists of the magnetic tape output from A/D. This tape is mounted on tape transport logical unit (1). Other input parameters are entered in the namelist using the teletype. The namelist parameters are as follows:

RINT = initial range to the nearest 2000 yard  
multiple, expressed as a real number.

SPANR = absolute value of maximum range voltage  
minus minimum range voltage.

SSCALE = gain of R channel amplifier used in  
program "A/D"



RSCALE = gain of R channel amplifier used in program "A/D".

BIAS = absolute value of bias voltage on the R channel signal.

FIRST = first record the operator desires to examine.

LAST = last record the operator desires to examine.

After the namelist parameters are entered, the program will read in records from the input tape. The records will not be stored until the record specified by FIRST is reached. At this point, 1024 values of S and R are placed in array IBUF. These values are then converted to 48 bit real numbers according to the following relation:

$$E = \frac{N \cdot 100.0}{2^{23} \cdot XSCALE} \quad (13)$$

where:  $E$  = input channel voltage

$N$  = 24 bit integer

$XSCALE$  = gain of R/S channel amplifier

The value of the converted S channel voltage is stored in the output array BUF. The value of the R channel is converted to range in yards. As seen in Figure (3), the servo driven potentiometer causes a discontinuity in the range voltage every 2000 yards. At the discontinuity the voltage changes almost instantaneously from a maximum to a minimum for decreasing ranges. Further, a small bias, 0.2 to 0.4 volts, is applied so that the range voltage changes sign at the discontinuity. When the program commences the range is initialized to within a 2000 yard multiple of the range recorded at the start of target track. For example, if the radar started tracking the target at 3600 yards, the



initial range (RINT) would equal 2000 yards. If the track started at 1650 yards, RINT would equal zero. The computer adds or subtracts 2000 yards from RINT each time the discontinuity is sensed. The computer determines the direction of the range increment by comparing the record average just prior to range voltage change from positive to negative, to a record average twenty-five records later. The actual value of range within the 2000 yard interval is computed from the relation,

$$R = \frac{V_R + V_B}{V_S} \times 2000 \quad (14)$$

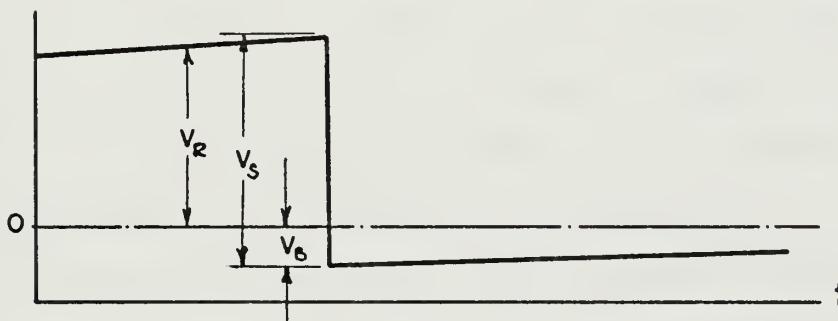


Figure (6)

where  $V_R$  = sampled range voltage

$V_B$  = range bias voltage

$V_S$  = range voltage span.

Average boxcar circuit voltage and average range are computed for each record as it is read from the input data tape. These averages are listed by the line printer and stored in core to be written on tape later, if desired. In addition, the pulse to pulse values of voltage and range can be listed on the line printer, record by record by energizing Sense Switch 2. Pulse to pulse values can be written on magnetic tape if a tape is mounted on a tape drive logical unit (2).



### 3. Program "FIT500"

The purpose of program "FIT500" is to derive the functional relationship between radar range and boxcar output voltage for the calibration track. The core of the program is subroutine LSQPL2, in modified form. Originally the subroutine was developed by D.E. Harrison in November, 1969, to perform a least-squares fit using 100 data points. Additionally, the subroutine performed a Chi-Square "goodness of fit" test and an F-Ratio test. In view of the extreme size of the input data base for program "SIGMA", the subroutine was expanded to handle up to 500 data points. Since core storage in the SDS 9300 is very limited, LSQPL2 had to be modified further by eliminating some of its additional features. The option to weight each data point was removed, as well as the Chi-Square test. The subroutine as it now exists will fit 500 data points and output the coefficients of the functional relation. Other outputs include a tabular listing of the independent variables, the dependent variables, computed dependent variables, and error.

Input data base for FIT500 consists of a magnetic tape mounted on tape drive logical unit (2). This tape should contain the average boxcar voltage and average radar range for each record as generated by the output option in program "DATA SHAPER". The namelist has only two entries:

RENUM = total number of records on the input tape

KKM = highest degree of fit desired.

Normally, KKM will be set equal to 2 whenever using program "SIGMA", since the relation between range and voltage is quadratic. However, FIT500 can be used alone to compute other functions provided KKM does not exceed 21.



Calibration tracks typically produced approximately 1000 records. FIT500 reads up to 1000 records and then computes the function using every other data pair. In order to read in all records without exceeding core storage, two subroutine arrays, Y and DELY, are used in addition to R and S, the input arrays. Only the data pairs in R and S are used for computation. The Y and DELY arrays are initialized to zero before calling LSQPL2.

#### 4. Program "SIGMAGEN"

The purpose of SIGMAGEN is to compute target radar cross section on a pulse to pulse basis. The input data base consists of the output tape from program "DATA SHAPER", on which are written boxcar output voltage and radar range from the target tracking run. Further, the coefficients of the quadratic relation between boxcar circuit voltage and range for the calibration track must be entered. As explained previously, these are computed by FIT500. The input data tape can be mounted on any tape drive, the logical unit being specified by INTAPE in the namelist.

After namelist parameters and output options have been specified by the operator on the teletype, the program causes the input tape to be read, one record at a time. The functional relation found by FIT500 is only valid over the interval of ranges used in calibration. As computation proceeds, boxcar voltages are read from array BUF, and the calibration range, RCAL, is found. If RCAL exceeds the calibration limits, it is discarded and a new boxcar voltage is read. Only when RCAL is within limits does a calculation for cross section occur. As the values for cross section, SIGMA, are computed, they are stored in the output buffer array DBUF. When the array is full, all 1024 values



of SIGMA and range are averaged. At this point, output can occur depending on the option selected. There are three different outputs from this program. The primary output of interest is the pulse to pulse listing of radar corss section and range. Secondly, the record averages can be printed out. Finally, an overall average SIGMA can be listed. It is conceivable that only a span of specific ranges is of interest, rather than the entire target track. To provide for this, the operator can specify the starting range by RSTART in the namelist. Similarly, RSTOP is entered as the last range of interest. The operator must also enter the radar cross section of the calibration sphere in square meters. Normally, a 6-inch aluminum sphere is used for calibration. In this case SPHR should be set equal to 0.01824.

It may be desirable to examine the target cross section even though the calibrated range is out of bounds. This can be done by executing Option (5) or (6). Output listings will then show all cross sections and ranges, with a minus sign before any range computed out of bounds.

The namelist inputs are:

MINLIM = range calibration, lower bound

MAXLIM = range calibration, upper bound

INTAPE = input tape drive logical unit

OUTAPE = output tape drive logical unit

SPHR = radar cross section, calibration sphere, meter<sup>2</sup>

B1,B2,B3 = coefficients of quadratic in ascending order

RSTART = first range in span of interest

RSTOP = last range in span of interest



The following is a list of options:

- Option (1) Output to line printer: mean SIGMA and mean RANGE for each record
- Option (2) Output to line printer: SIGMA and RANGE pulse by pulse
- Option (3) Output to tape and line printer: mean SIGMA and mean RANGE for each record
- Option (4) Output to tape and line printer: SIGMA and RANGE pulse by pulse
- Option (5) Defeat calibration bounds. Output to line printer: SIGMA and RANGE pulse by pulse
- Option (6) Defeat calibration bounds. Output to line printer: mean SIGMA and mean RANGE for each record
- Option (7) Read in new namelist
- Option (8) Stop the program



## V. CONCLUDING REMARKS

Although SIGMA provides the ground work for computing radar cross sections on a pulse to pulse basis, there are many extensions and some modifications which would expand the usefulness and facility of dynamic target measurement.

It is recognized that SIGMA, as presently written in four parts, does not represent optimal programming. While partitioning was useful for development, the program could be consolidated by utilizing segmented format in the overlay structure of the SDS 9300. This would also reduce the need for large amounts of digital tape.

An examination of the introduction of noise and subsequent error generation would be relevant. The present equipment and methods for recording the analog tape, which is the basic input to the entire computer program, leave room for improvement. In addition to tape hiss, wow and flutter, and switching transients, a certain amount of noise is introduced by the physical location of the tape recorder with respect to the radar equipment racks. Some consideration should be given to the use of a Dolby Noise Reduction package.

The use of the MK 25 Radar imposes certain restrictions. This radar uses a conical scan and therefore causes the returned signals to be modulated at the scan frequency. While a correlation technique could be used in the computer program to account for scan modulation, a better approach would be to use a monopulse radar. The NIKE-AJAX radar system, for example, could provide a better foundation on which to build an instrumentation range.



Finally, regardless of the radar system used, the computer program could be extended to handle target azimuth, elevation and range rate. Instrumentation on airfoil controls, as well as target attitude should also be included. Armed with these inputs, program "SIGMA" could be interfaced with an Adage Graphics Terminal or similar display device for three-dimensional analysis of target aspect and cross section.



PROGRAM: A/D

PURPOSE: SAMPLES ANALOG INPUT AND CONVERTS TO DIGITAL DATA,  
OUTPUTS TO MAGNETIC TAPE, PLUS ADDITIONAL OPTIONS.

SAMPLING RATE: UP TO 12,000 SPS

PREPARED BY R. LIMES JAN 1971  
MODIFIED FOR SIGMA BY F. MEYER APR 1971

NAMELIST INPUTS:

NREC = TOTAL NUMBER RECORDS TO BE PLACED ON OUTPUT TAPE  
NCHAN = NUMBER SIGNALS TO BE DIGITIZED  
NSAMP = 2048/NCHAN  
ITAPE = LOGICAL UNIT TAPE OUTPUT  
NDEL = NUMBER MILLISECS(TIMES 11.0) DELAY BETWEEN DAC  
OUTPUTS FOR OPTION (7).

LIST OF OPTIONS:

- (1) CHANGE PARAMETER NAMELIST
- (2) CONVERT AND OUTPUT TO MAG TAPE
- (3) OUTPUT 'END OF FILE' TO TAPE
- (4) READING TAPE
- (5) SKIP FILES
- (6) OUTPUT TO LINE PRINTER



(7) OUTPUT TO ANALOG STRIP CHART RECORDER FROM TAPE.  
(SENSE SWITCH 1 MUST BE ON FOR CONTINUOUS OPERATION.)

C SENSE SWITCH 1: ON -CONTINUOUS OPERATION OPTION (7)  
C OFF -SELECT OPTION  
C SENSE SWITCH 2: ON -OUTPUTS ONLY ONE RECORD TO STRIP CHART.  
C OFF -CONTINUOUS OPERATION OPTION (7).  
C  
C PROGRAM A/D STARTS HERE.  
C.  
C. DIMENSION IBUF(2048,2),LACB(-1:1),MAXBS(-1:1)  
C. INTEGER RECNM  
C. NAMELIST NREC, NSAMP, NCHAN, ITAPE, NDEL  
C  
C OPTION (1) INPUT NEW NAMELIST  
C  
C 1 INPUT(101)  
C LACB(-1)=LACF(1BUF(1,1))  
C LACB(1)=LACF(1BUF(1,2))  
C NWARDS=NSAMP\*NCHAN  
C MAXBS(-1)=LACB(-1)+NWARDS-1  
C MAXBS(1)=LACB(1)+NWARDS-1  
C IND=0  
C IF(SENSE SWITCH 6)2,15  
C  
C 2 OPTION (2) CONVERT A TO D OUTPUT TO TAPE  
C  
C 3 NB=1  
C RECNM=C  
C NEWBUF=LACB(1)  
C MAXB=MAXBS(-1)  
C CALL ADSTART(NCHAN,LACB(-1),NEWBUF,MAX3,RECNM,11S)  
C MAXB=MAXBS(1)  
C IF(TEST(1).GT.0) GO TO 3



```

5      CALL ENABLE
      CONTINUE
10     GO TO 5
11     IF(IND.EQ.1)GO TO 90
11     IF(TEST(1).GT.0.OR.RECNUM.GE.NREC)CALL DISABLE
      NR=NB
      NEBUF=LOCB(NB)
      MAXB=MAXBS(NB)
      IND=1
      CALL BUFLRUT(ITAPE,1,IBUF(1,(3+NB)/2),NWRS,IND)
      IF(TEST(1).LT.0.AND.RECNUM.LT.NREC)GO TO 5
      CALL AOSTP
      CALL PROCESS(IBUF,NSAMP,NCHAN,2S)
      X      OUTPUT(1C1)RECNUM
      OUTPUT(1C1)'OPTION=(11)'
      15     READ(101,100)NPT
      100    FORMAT(11)
      GO TO(1,2,30,40,50,60,70)NPT
      C      OPTION (3) OUTPUT 'END OF FILE' TO TAPE
      C      ENDFILE(ITAPE)
      C      OUTPUT(101)'EOF'
      30     GO TO 15
      C      OPTION (4) REWIND TAPE
      C      REWIND(ITAPE)
      C      GO TO 15
      C      OPTION (5) SKIP FILES
      C      OUTPUT(101)'SKIPFILES=(14)'
      40     READ(101,101)N
      50     FORMAT(14)
      101

```



```

DE 55 I=1,NF
CALL BUFFERIN(ITAPE,1,IBUF(1,1),1,IND)
51 IF(IND.LT.2)30 T0 52
52 IF(IND.NE.3)30 T0 51
CONTINUE
55 OUTPUT(101)NF
CD TO 15

C   OPTION (6) OUTPUT TO LINE PRINTER
C
60 OUTPUR(101)'NUMWORDS T9 LIST=(14)'

READ(101,101)NW
WRITE(101,105)NW,NCHAN
FORMAT(14,WORDS,12,'AT A TIME')
105 IND=1
CALL BUFFERIN(ITAPE,1,IBUF(1,1),NWNRDS,IND)
IF(IND.EQ.1)GO T0 66
66 G9 T9(62,63,64,65)IND
62 WRITE(6,1C2)
63 WRITE(6,1C2)
FORMAT(1H1)
64 631 I=1,Na,NCHAN
WRITE(6,104)(IBUF(J,1),J=1,I+NCHAN-1)
FORMAT(12a10)
631 CONTINUE
CD TO 15
64 OUTPUT(101)'E9F RFAD'
65 OUTPUT(101)'READ ERR'
CD TO 63

C   OPTION (7) OUTPUT TO STRIP CHART RECORDER
C
70 OUTPUT(101)'START ANALOG RECORDER'
OUTPUT(101)'TYPE * C/R T9 CONTINUE'
INPUT(101)

```



```

77  IND=1
    CALL BUFFERIN(ITAPE,1,IBUF,NWORDS,IND)
    IF(IND.EQ.1)39 T9 76
    GO T9(71,72,64,74)IND
71    DA 73 I=1,NWORDS
72    DA 73 I=1,NWORDS
73    IBUF(I,1)=IBUF(I,1)/2**10
    GO 75 I=1,NWORDS,NCHAN
74    GO 75 J=1,NCHAN
    CALL DAC(J,IBUF(I+J-1,1))
N=NDEL
    CALL DELAY
    IF(SENSE SWITCH 2) 15,75
    CONTINUE
    IF(SENSE SWITCH 1)77,15
    OUTPUT(101)'READ ERROR'
    GO T6 72
    CALL DISABLE
    CALL ADSION
    OUTPUT(101)'RATE ERR',RECNUM
    GO T9 15
END

```

```

SUBROUTINE PROCESS(IB,NS,NC,IS)
N=50000
CALL DELAY
    IF(TEST(1).LT.0)GO T9 30
    IF(TEST(2).GT.0)RETURN
    RETURN IS
END

```

```

$ADSTART PZE          9SETUPN
BRM          6
PZE

```



```

NCH PZE
RUF PZE
NEWBUF PZE
MAXB PZE
RECNUM PZE
NEXTLOC PZE
LDA END3RM
XMA 04C
STA SVO40
LDA INTBRM
XMA 052
STA SVO52
LDA *NCH
STA INCR
ADD =C6MM
COPY (5,1)
STA COLLEC
LDA *NCH
LLSA 15
ADD =C6MM
STA 0,1
STA CONTR
LDA *BUF
STA COMM
LDA *MAXB
STA MAX
SKR NFULL
BRU $-1
E9M 034001
PAT CONTR
BRR ADSTART
ENDAD ADFAST
INTBRM BRM
END3RM BRM
SVO40 PZE
ENDAD PZE

```



```

DIR      HLT      034001
        E9M      CENTR
        P8T
        EIR      *ENDAD
        BRC      *ADFAST PZE
        $ADFAST PZE

        BRC      PZE
        LDA      SV040
        STA      040
        LDA      SV052
        STA      052
        STZ      *COML9C
        MP0      ADSTOP
        BRR      ADSTOP

        COML9C PZE
        $ADFAST PZE

DIR      STD      SVAB
        SKN      NFULL
        BRU      NXTBUF
        LDP      INCR
        ADD      COMM
        STA      COMM
        ADD      INCR
        SKL      MAX
        STB      NFULL
        LDP      SVAB
        EIR      *ADFAST
        BRC      LDA
        STA      *NEW3UF
        LDA      COMM
        STA      *MAXB
        SKR      MAX
        BRU      NFULL
        $-1

```







PROGRAM: DATA SHAPER

PREPARED BY F.E. MEYFTT APR 1971

THIS ROUTINE CONVERTS THE DATA TAPE VOLTAGES TO SIGNAL  
STRENGTH AND RADAR RANGE, AND WRITES THIS DATA ON TAPE.  
THE INPUT DATA TAPE MAY BE ADVANCED TO START AT SOME RECORD  
OTHER THAN THE FIRST BY SETTING 'FIRST' EQUAL TO THE DESIRED  
STARTING RECORD. IN A SIMILAR MANNER THE INPUT DATA TAPE  
MAY BE STOPPED BY ENTERING THE LAST RECORD NUMBER EQUAL  
TO 'LAST'. 'FIRST' MUST BE GREATER THAN 1.

OUTPUTS: IF END OF FILE IS ENCOUNTERED ON THE INPUT TAPE  
THE TOTAL NUMBER OF RECORDS AND TOTAL NUMBER OF DATA  
POINTS IS LISTED ON THE TYPewriter.

AVERAGE SIGNAL STRENGTH AND AVERAGE RADAR RANGE  
ARE OUTPUT TO THE PRINTER AS WELL AS RECORD NUMBER FOR  
EACH RECORD AS IT IS READ.

ON COMMAND AN ENTIRE RECORD MAY BE PRINTED OUT.

ON COMMAND THE AVERAGE SIGNAL STRENGTH AND  
RADAR RANGE MAY BE OUTPUT TO MAGTAPE(1).

ON COMMAND MAGTAPE(1) MAY BE READ BACK AND  
PRINTED OUT.



SENSE SWITCH 1 ON STOPS THE ROUTINE, BUT DOES NOT  
NEGATE OPTION TO OUTPUT TO MASTAPE(1). PUSH SENSE  
SWITCHES 1 AND 3 TOGETHER TO REMOVE OPTION.  
SENSE SWITCH 2 ON WILL OUTPUT AN ENTIRE RECORD.  
SENSE SWITCH 4 OFF WILL OUTPUT A READ BACK FROM  
TAPE(1) IF OPTION WAS USED

### NAMELIST INPUTS:

RINT = INITIAL RANGE  
 SPAN = RANGE VOLTAGE SPAN  
 SSCALE = AMPLIFIER GAIN SIGNAL CHANNEL  
 RSCALE = AMPLIFIER GAIN RANGE CHANNEL  
 BIAS = BIAS VOLTAGE RANGE CHANNEL  
 FIRST = NUMBER OF FIRST RECORD TO BE PROCESSED  
 LAST = NUMBER OF LAST RECORD TO BE PROCESSED

PROGRAM DATA SHAPER STARTS HERE

```

DIMENSION BUF(2048),IBUF(2048),RAVE(1500),SAVE(1500)
INTEGER RECNUM,COUNT,FIRST,LAST,Z
NAMELIST RINT,SPAN,SSCALE,BIAS,RSCALE,FIRST,LAST

```



```

C INPUT(101)
C ADVANCE TAPE TO FIRST RECORD
C
C Z=FIRST-1
D0 999 J=1,Z
  I=1
    CALL BUFFERIN (1,1,IBUF,2048,I)
998 IF(I*EC•1) GO TO 998
  GO TO (998,999,999,999) I
999 CONTINUE
  COUNT=20
  RAVE(1)=2000.0
  Y=1
  K=0
  RECNUM=0
  1 IF(SENSE SWITCH 1)100,5
  5 I=1
C READ ONE RECORD, FILL BUFFER
C
C CALL BUFFERIN(1,1,IBUF,2048,I)
6 IF(I*EC•1) GO TO 6
  GO TO (6,8,100,7) I
  7 OUTPUT(101) 'ERROR READ'
  8 J=1
C CONVERT SIGNAL (ECTAL) TO SIGNAL (FLOATING POINT)
C
C IBUF(J)=1.0-(IBUF(J)*100.0/2**23)/SSCALE
  J=J+1
C CONVERT RAMP VOLTAGE (ECTAL) TO RANGE (FLOATING POINT)
C
C VOLTSR=(IBUF(J)*100.0/2**23)/RSCALE

```



```

C C RNEW=((VOLTSR+BIAS)/SPANR)*2000.0
C C X=RAVE(1)-RINT
C C TEST FOR 2000 YD. MARK/RANGE INCREASING
C C IF((VOLTSR.LT.0.0).AND.(X.GT.1000.0).AND.(K.EQ.1)) GO TO 50
C C TEST FOR 2000 YD. MARK/RANGE DECREASING.
C C IF((VOLTSR.GT.0.0).AND.(X.LT.500.0).AND.(K.EQ.1)) GO TO 55
C C 10 RUF(J)=RINT+RNEW
C C J=J+1
C C IF((J.GE.2049) GO TO 60
C C GO TO 2
C C 50 RINT=RINT+2000.0
C C K=0
C C COUNT=0
C C GO TO 10
C C 55 RINT=RINT-2000.0
C C K=0
C C COUNT=0
C C GO TO 10
C C
C C STFP RECORD NUMBER,COUNTER
C C 60 RECNUM=RFCNUM+1
C C M=RECNUM
C C IF(M.GE.LAST) GO TO 100
C C COUNT=COUNT+1
C C IF(COUNT.EQ.25) K=1
C C
C C COMPUTE AVERAGE SIGNAL AND RANGE
C C SSUM=0.0
C C 60 70 KK=1,2047,2

```



```

70  CONTINUE
    RSUM=0.0
    D6 71 KK=2,2048,2
    RSUM=RSUM+BUF (KK)
71  CONTINUE
    SAVE (M)=SSUM/1024.0
    RAVE (M)=RSUM/1024.0
    WRITE(6,72) RECNUM,SAVE (M),RAVE (M),K
72  FORMAT(14.5X,F11.4,5X,F11.4,5X,14)
C   SELECT OPTION TO PRINT ALL POINTS IN RECORD
C
    IF(SENSE SWITCH 2) 73,80
73  WRITE(6,74) RECNUM
    .
74  FORMAT('RECNUM',14)
    D8 77 I=1,2048,2
    WRITE(6,76) (BUF (M),M=1,I+1)
76  FORMAT(F11.4,10X,F11.4)
77  CONTINUE
78  WRITE(6,79) RECNUM
79  FORMAT('END RECNUM',14)
80  N=1
C   OUTPUT ALL CONVERTED DATA POINTS TO TAPE(2).
C
    CALL BUFFEROUT(2,1,BUF,4096,N)
81  IF(N.EQ.1) 69 T0 81
    IF(N.EQ.4) 69 T0 82
    69 T0 1
82  OUTPUT(101)'ERROR WRITTEN'
    68 T0 1
100 OUTPUT(101)'END OF FILE'
    NUMPTS=RFCNUM*1024
    OUTPUT(101)RFCNUM,NUMPTS

```



2  
三  
上  
卷

```

REWIND 2
REWIND 1
C
C   SELECT OPTION TO OUTPUT AVERAGES TO TAPE(1).
C
C   IF(SENSE SWITCH 3) 110,101
C     OUTPUT(101)'REMOVE TAPE,UNIT(1), MOUNT TAPE,UNIT (3) '
C     OUTPUT(101)'TYPE * C/R T9 CONTINUE,
C     INPUT(101)
C     WRITE(3)' (SAVE(J),RAVE(J),J=1,RECNUM)
C     END FILE 3
C
C   REWIND 3
C
C   SELECT OPTION TO RECORD CHECK TAPE(1).
C
C   IF(SENSE SWITCH 4) 110,104
C     DE 105 J=1,RFNUM
C     SAVE(J)=0.0
C     RAVE(J)=0.0
C
C   CONTINUE
C   READ(3)' (SAVE(J),RAVE(J),J=1,RECNUM)
C   WRITE(6,106)' (SAVE(J),RAVE(J),J=1,RECNUM)
C   104 FORMAT(F11.4,10X,F11.4)
C   105 CONTINUE
C   106 FORMAT(F11.4,10X,F11.4)
C   REWIND 3
C
C   110 STOP
C

```



PROGRAM: FIT500

PREPARED BY F.E. MEYETT    MAY 1971    FOR SIGMA

PURPOSE:    READS UP TO 1000 DATA PAIRS OF RANGE (R) AND SIGNAL (S) AND COMPUTES THE FUNCTIONAL RELATION WITH SIGNAL (S) AS THE INDEPENDENT VARIABLE. EVERY OTHER DATA PAIR IS USED FOR THE LEAST SQUARES FIT SO THAT A MAXIMUM OF 500 POINTS MAY BE FITTED.

REMARKS:    MAINT INPUT DATA TAPE ON LOGICAL UNIT (2).

NAMELIST INPUTS:  
RECNUM    =TOTAL NUMBER OF RECORDS IN INPUT DATA TAPE  
KKM    =HIGHEST DEGREE OF FIT DESIRED. (SET KKM=2 FOR  
SIGMA.)

SUBROUTINE: LSQPL2

A. IDENTIFICATION:  
TITLE: LEAST SQUARES POLYNOMIAL FITTING  
CATEGORY: CURVE FITTING

PROGRAMMED BY D.E.HARRISON, NOV 1969.



MODIFIED BY R.HILLFARY, FEB 1970.  
MODIFIED BY R.E. RINKFR OCT 1970.  
MODIFIED BY F.E. MEYETT APR 1971 FOR SIGMA

B. PURPOSE:  
C GIVEN ARRAY X AND ARRAY F, WHERE F(I) IS THE OBSERVED DEPENDENT  
C VARIABLE AND X(I) IS THE OBSERVED INDEPENDENT VARIABLE, THE  
C POLYNOMIAL  $Y = B(1) + B(2) * X + \dots + B(K+1) * X^{K+1}$  IS FITTED FOR ALL DEGREES  
C K,  $1 \leq K \leq K(\text{MAX})$ .

C. USAGE

1. CALLING SEQUENCE:  
CALL LSQPL2(M,K,X,F2,Y,DELY,B,SB,TITLE)

2. ARGUMENTS:

M - NUMBER OF DATA POINTS, M.LE.500 (INTEGER)  
K - THE ABSOLUTE VALUE OF K IS THE MAXIMUM DEGREE OF FIT  
TO BE CONSIDERED. IF KM.GE.1, DATA FOR ALL DEGREES OF  
FIT BEGINNING WITH ONE (LINEAR) AND UP TO KM ARE PRINTED.  
IF KM.LE.-1, DATA FOR THE DEGREE OF FIT, ABS(KM), ONLY  
ARE PRINTED. RESTRICTION: ABS(KM).LE.20  
X - THE ARRAY OF OBSERVED INDEPENDENT VARIABLES (REAL)  
F2 - THE ARRAY OF OBSERVED DEPENDENT VARIABLES (REAL)  
Y - THE OUTPUT ARRAY OF ESTIMATED DEPENDENT VARIABLES (REAL)  
DELY - THE OUTPUT ARRAY OF THE DIFFERENCES BETWEEN F2 AND Y  
B - THE OUTPUT ARRAY OF THE COEFFICIENTS OF THE POWERS OF X IN  
THE POLYNOMIAL FIT (REAL)  
SB - THE OUTPUT VALUES OF THE ESTIMATES OF ERROR IN B (REAL)  
TITLE - HEADING FOR OUTPUT TABLES.

PROGRAM FIT500 STARTS HERE

DIMENSION R(500),S(500),Y(500),B(500),SB(500),TITLE(10),DELY(500)  
INTEGER RECNM,NUMPTS,KM  
NAMELIST RECNM,KM



```

INPUT(101)
NUMPTS=RFCNUM/2
C
C READ INPUT DATA TAPE
C
C READ(2) (S(I),R(I),Y(I),DELY(I),I=1,NUMPTS)
C
C RECORD CHECK
C
C WRITE(6,50) (S(I),R(I),Y(I),DELY(I),I=1,NUMPTS)
50 FORMAT(F11.4,5X,F11.4,5X,F11.4,5X,F11.4)
C
C ZERO Y AND DELY ARRAYS
C
D9 10 J=1,NUMPTS
Y(J)=0.0
DELY(J)=0.0
C
10 CONTINUE
C
C WRITE(6,100) RECNUM,NUMPTS,KKM
100 FORMAT(5X,'RECNUM=',I4,5X,'NUMPTS=',I3,5X,'KKM=',I1)
CALL LSQPL2(NUMPTS,KKM,S,R,Y,DELY,B,SB,TITLE)
REWIND 2
STOP
END

SUBROUTINE LSQPL2(M,KM,X,F2,Y,DELY,B,SB,TITLE)
INTEGER TITLE(10)
REAL X(1),F2(1),Y(1),DELY(1),B(1),SB(1),
XF,FM,FMR,PXF,PXP,XPXP,XPXPM,PPXPM,PPXF,FBAR,XBAR,
XF(500),P(500),PM(500),ST(500),S(500),A(21,21),T(500)
1,SIG2,SIG3,SUMEV2,FLFV,F2BAR,SQ,FMF,FMF,FMF,AM,CHI
D9 1 I=1,21
D0 1 J=1,21
1 A(I,J)=0.0

```



```

A(1,1)=1.0
A(2,2)=1.0
PBAR=0.0
SUMEV2=0.0
FM=0
FMR=1.0000/FM
F3AR=C.0
YBAR=0.0
D9 10 I=1,M
W=F*Y2
PM(I)=SQRT(W)
F(I)=F2(I)*PM(I)
SUMEV2=SUMEV2+F2(I)
FBAR=FBAR+F(I)*PM(I)
10 XBAR=XBAR+X(I)*W
T(I)=F*BAR
A(2,1)=-XBAR
PXF=0.0
PXP=0.0
F2BAR=SUMEV2/FM
SUMEV2=0.00
D9 20 I=1,M
SUMEV2=SUMEV2+W*(F2(I)-F2BAR)**2
P(I)=(X(I)-XBAR)*PM(I)
FXF=PXF+P(I)*F(I)
20 PXP=PXP+P(I)*P(I)
MFY=FM+C.00001
T(2)=PXF/PXP
PN*PM=1.000
S(1)=PN*PM
KMP=1+SS(KM)+1
B(1)=T(1)*A(1,1)+T(2)*A(2,1)
B(2)=T(2)*A(2,2)
D9 1000 K=2,M
CHI=0.

```



```

KM1=K-1
KM2=K-2
IF (KM2.EQ.0) GO TO 200
XPXP=0.0
YXPY=0.0
B(K)=0.0
D 50 J=1,M
XP=X(J)*P(J)
XPXP=XF*XP+XP*P(J)
50 XPXPY>PXPY+XP*PY(J)
ALPHA=XPYP/PYP
BETA=XPYPY/PN*XPY
PPXF=0.0
PPXP=0.0
DA 100 I=1,M
FT=P(I)
P(I)=(Y(I)-ALPHA)*P(I)-BETA*PM(I)
PPXF=PPXF+P(I)*F(I)
PPXP=PPXP+2(I)*P(I)
100 PM(I)=0.0
I(K)=PPXF/PPXP
PNXPY=PPXP
PPXP=PPXP
A(K,1)=ALPHA*A(KM1,1)-BETA*AM(KM2,1)
A(K,KM1)=A(KM1,KM2)-A(KM1,KM1)*ALPHA
A(K,K)=1.0
IF (K.LE.3) GO TO 150
D 120 I=2,KM2
120 A(K,I)=A(KM1,I-1)-ALPHA*A(KM1,I)-BETA*A(KM2,I)
150 D 160 I=1,K
160 F(I)=B(I)+T(K)*A(K,I)
200 S1G3=0.0
DA 220 I=1,M
SQ=B(K)
KK=K-1

```



```

D6 230 I0=1,4KG
      KM10=K-10
230  SQ=X(I)*SQ+B(KM10)
      Y(I)=SQ
      DELY(I)=Y(I)-F2(I)
220  SIG3=SIG3+K*DELY(I)**2
      F4KF=MF*~-K
      SIG2=SIG3*FM/F4KF
      FLFV=(SUMEV2-SIG3)/SIG2
      SUMEV2=SIG3
      SUMEV2=SIG2
      S(K)=PXP
      .
      D9 240 I=1,K
240  ST(I)=SIG2/S(I)
      D9 300 I=1,K
      SH(I)=C*0
      D9 250 J=1,K
      .
250  SB(I)=SB(I)+ST(J)*A(J,I)**2
300  SB(I)=SORT(SB(I))
      IF(KM+GT.OGE T0 301
      CANTINUE
      IF(K.LT.KMP)G9 T0 1000
      .
301  CONTINUE
      KRTF(6,9510) (TITLE(1),I=1,10)
9510  FORMAT(1H1,20X,10A8,//,20X,'COEFFICIENTS OF THE POWER SERIES EXPAN
      XSIAN',//,20X,'Y(X)=B(1)+B(2)*X+B(3)*X**2+B(4)*X**3+...',//)
      WRITE(6,9520) ((1,B(I)),I=1,K)
9520  FORMAT(6(1,3(1,12,1)=1,1PE12.5))
      WRITE(6,9530)
      9530  FORMAT(//,2CY,'ESTIMATES OF ERROR FOR THE COEFFICIENTS',//)
      WRITE(6,9540) ((1,SB(I)),I=1,K)
9540  FORMAT(6(1,ERRB(I,I2,I)=1,1PE9.3))
      WRITE(6,9570) SIG3,FLEV
      9570  FORMAT(//,3X,'SUM SQ DEV =',1PE10.3,10X,'F-RATIO =',1PE10.3)
      D9 25 IRI=1,
      25 CHI=CHI+DELY(IRI)*DELY(IRI)/ABS(Y(IRI))

```



```

1111 WRITE(6,1111)CHI,FMKF
      FORMAT('0 CHISG=','1PE11.3,7X,' DEG 9F  FREEDOM =',OPF4.0)
      WRITE(6,9550)
9550 FORMAT(//,1
      XLY(I),//)
      WRITE(6,9560) (I,X(I),F2(I),Y(I),DELY(I),I=1,M)
9560 FORMAT(14,2X,OPF11.4,2X,1PE15.7,2X,1PE15.7,2X,1PE15.7)
1000 CONTINUE
      RETURN
      END

```



PROGRAM: SIGMAGEN

PREPARED BY F.E. MEYER APR 1971 FOR SIGMA

PURPOSE: COMPUTATION OF RADAR CROSS SECTION FROM A MAGNETIC TAPE  
INPUT TAPE MUST HAVE BEEN PREVIOUSLY PREPARED USING SUBROUTINE  
'BUFFERIN'.

OUTPUT FLEXIBILITY IS PERMITTED BY THE USE OF OPTIONS LISTED BELOW:

- OPTION (1) OUTPUT TO LINE PRINTER: MEAN SIGMA, MEAN RANGE FOR EACH RECORD.
- OPTION (2) OUTPUT TO LINE PRINTER: SIGMA AND RANGE POINT BY POINT.
- OPTION (3) OUTPUT TO TAPE AND LINE PRINTER: MEAN SIGMA AND MEAN RANGE FOR EACH RECORD.
- OPTION (4) OUTPUT TO TAPE AND LINE PRINTER: SIGMA AND RANGE POINT BY POINT.
- OPTION (5) DEFEAT CALIBRATION BOUNDS LIMIT. OUTPUT TO LINE PRINTER: SIGMA AND RANGE, POINT BY POINT. A MINUS SIGN PRECEDING RANGE INDICATES COMPUTED OUT OF BOUNDS.
- OPTION (6) DEFEAT CALIBRATION BOUNDS LIMIT. OUTPUT TO LINE PRINTER: MEAN SIGMA AND MEAN RANGE FOR EACH RECORD.
- OPTION (7) READ IN NEW NAMELIST DATA.
- OPTION (8) STOP THE PROGRAM.



NAMELIST INPUT DATA:

MINLIM = MIN. CALIBRATION RANGE, YARDS  
MAXLIM = MAX. CALIBRATION RANGE, YARDS  
INTAPE = LOGICAL UNIT INPUT TAPE  
OUTAPE = LOGICAL UNIT OUTPUT TAPE  
SPHR = CROSS SECTION OF CALIBRATION SPHERE, SQ. METERS  
          (FOR 6-INCH SPHERE ENTER '0.01824')  
B1,B2,B3 = COEFFICIENTS FOUND BY SUBROUTINE 'FIT500'  
RSTART = FIRST RANGE IN SPAN OF RANGES TO BE EXAMINED, YDS  
RESTP = LAST RANGE IN SPAN OF RANGES TO BE EXAMINED, YDS

PROGRAM SIGNAGEN STARTS HERE

DIMENSION BUF(2048),DBUF(2048)  
REAL MINLIM,MAXLIM  
INTEGER FEGNUM,OUTAPE  
NAMELIST MINLIM,MAXLIM,INTAPE,OUTAPE,SPHR,R1,B2,B3,RSTART,RSTOP  
1 INPUT(101)  
5 OUTPUT(101) OPTION=(11)  
C INPUT OPTION FOR OUTPUT  
C  
READ(101,100)NPT  
100 FORMAT(11)  
  IF(NAP1\*FQ>7) GO TO 1  
  IF(NAP1\*FQ<8) GO TO 99  
10 FEGNUM=0  
  SIGRT=0.0  
  RTORT=0.0  
  M=0







```

C COMPUTE CALIBRATED RANGE
C
C 17 RCAL=B1+B2*STGT+23*STGT**2
C J=J+1
C K=0
C
C TEST FOR CALIBRATED RANGE IN BOUNDS. IF TEST FALSE, SET SIGMA=0.0,
C AND STEP COUNTER
C
C IF((RCAL.LE.MINLIM).AND.(RCAL.LE.MAXLIM)) GO TO 20
C K=1
C
C TEST FOR OPTIONS 5 AND 6
C
C IF((NOPT.EQ.5).OR.(NOPT.EQ.6)) GO TO 20
C COUNT=COUNT+1.0
C SIGMA=0.0
C GO TO 25
C
C COMPUTE SIGMA
C
C 20 SIGMA=(RTGT**4)/(RCAL**4)*SPHR
C 25 M=M+1
C D3UF(M)=SIGMA
C M=M+1
C D3UF(M)=RTGT
C IF(K.EQ.1) D3UF(M)=RTGT
C
C TEST FOR OUTPUT RECORD BUFFER FULL
C
C 30 IF(M.LT.2048) GO TO 15
C RECNUM=RECNUM+1
C SSUM=0.0
C GO TO 31 I=1,2047,2

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31  CONTINUE
      RSUM=0.0
      DO 32 I=2,2048,2
      RSUM=RSUM+ABS(DBUF(I))
32  CONTINUE

C COMPUTE RECORD AVERAGES
C
C SIGAVE=SSUM/(1024.0-COUNT)
      RTGAVE=RSUM/1024.0
      SIGRT=SIGRT+SIGAVE
      RTGRT=RTGRT+RTGAVE

C COMPUTE OVERALL MEANS
C
C STAVE=SIGRT/AINTR(COUNT)
      RTAVE=RTGRT/AINTR(COUNT)
      COUNT=0.0

C OUTPUT OPTIONS BEGIN HERE
C
C 69 T9 (40,50,60,70,50,40)N9PT
      40 WRITE(6,102)RECHUM,SIGAVE,RTGAVE
      102 FORMAT(3X,'RECORD NO.=',I4,5X,'MEAN SIGMA=',F9.2,5X,'MEAN RANGE=',F9.2)
      41 M=0
      68 T9 15
      50 WRITE(6,103)RECNUM
      103 FORMAT(//,'START RECORD NUMBER',I4,//)
      51 WRITE(6,104)
      104 FORMAT(5X,'SIGMA',RANGE',//)
      52 WRITE(6,105) (DBUF(N),N=K,K+1)
      105 FORMAT(3X,F9.2,6X,F9.2)

```



```
53 CONTINUE
54 WRITE(6,106) RFCNUM
106 FORMAT(//,'END RECORD NUMBER',I4,/)
GO TO 40
60 WRITE(OUTAPE) SIGAVE,RTGAVE
GO TO 40
70 IND=1
    CALL BUFFEROUT(OUTAPE,1,DBUF,4096,IND)
71 IF(IND.EQ.1) GO TO 71
    IF(IND.EQ.4) GO TO 72
    GO TO 50
72 OUTPUT(101)'ERROR WRITTEN'
GO TO 50
90 REWIND(INTAPE)
END FILE(OUTAPP)
```

REWIND(OUTAPE)

C LOOP BACK TO INPUT OPTION

C

C

60 TO 5

99 STEP

END



### LIST OF REFERENCES

1. Naval Missile Center Technical Memorandum RM-67-44, An Operational Method For Measuring Radar Cross Section Of An Airborne Target, by F.T. Cunningham, 30 August 1967.
2. Skolnik, M.I., Introduction to Radar Systems, p.40-50, McGraw-Hill, 1962.



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13. ABSTRACT This paper describes the design and use of SIGMA, a computer program for the calculation of radar cross section of a dynamic target on a pulse to pulse basis, using the MK 25 Fire Control Radar. The program is written specifically for use on the Scientific Data Systems 9300 computer in FORTRAN IV, but is readily adapted to other data processing systems. The input data base is composed of magnetic tape recordings of instrumented radar range and signal strength. Outputs include target cross section and range, and mean cross section and range in printed tabular listing, in graphical form, and on digital magnetic tape.			



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